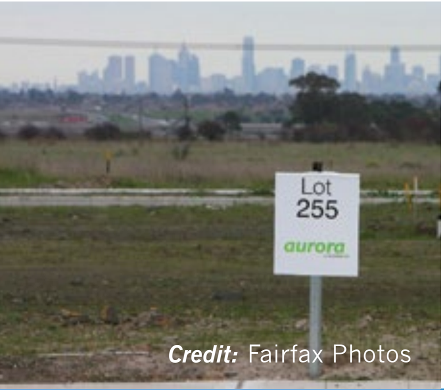
victorian centre for climate change adaptation research

July **2012**
Climate Adaptation for **Decision makers**



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Resilient urban systems: Lessons from community-scale infrastructure for climate change adaptation

Final Policy Brief

ontributors
Paula Arcari, Che Biggs, Cecily Maller, Yolande Strengers, Ralph Horne, Chris Ryan

Key Points

Resilience of community-scale infrastructure systems is a dynamic state that results from the interaction of diverse and context-specific technical, institutional and social factors. In particular, in conditions of uncertainty, social and institutional enablers, such as knowledge, context, agency, and clear lines of responsibility, become more important than technical enablers for building community resilience.

Community-scale water systems have the potential to increase the resilience of communities reliant on them, through their capacity to avoid, absorb and adjust to climate related shocks. However, they are ultimately reliant on mains energy and water networks and are therefore at risk from impacts on centralised infrastructure.

Design and planning of infrastructure in urban developments without specific attention to social and institutional arrangements may undermine community resilience. However, social and institutional enablers of resilience can be fostered by policy makers, developers, utility providers and other stakeholders.

Fostering the integration of community-scale energy and water systems within larger infrastructure systems may increase the overall resilience of urban energy and water systems.

Victoria's regulatory landscape poses few direct barriers to community-scale systems but can restrict further innovation that may increase infrastructure resilience (eg the current regulatory environment for electricity prevents grid-connected community-scale energy systems from functioning 'off-line' while the mains grid is down).

Outcomes of this research include:

- A preliminary set of technical, institutional and social enablers of resilience;
- An initial conceptual framework indicating the relative value of resilience enablers under uncertainty; and
- Preliminary assessment criteria for improving the resilience of community-scale urban infrastructure.

Victoria's regulatory landscape poses few direct barriers to replicating WestWyck and Aurora-style developments but restricts further innovation that may increase infrastructure resilience.

Background

Conventional energy and water systems are centralised in the way they are configured and controlled, and these arrangements divide stakeholders into providers and consumers. This research considers how community-scale energy and water infrastructure may support or undermine community resilience to climate change in Victoria, including by reconfiguring the social and institutional arrangements of supply. The research project was set up as a pilot investigation, and involved a detailed investigation of two case study infrastructure systems in Melbourne—Westwyck Ecovillage in Brunswick West and Places Victoria's (previously known as VicUrban) Aurora development in Epping. Findings are preliminary and indicative.

Over the last two decades, changing community concerns, market deregulation and technical innovation have supported the development and adoption of 'localised' infrastructure systems. In particular, community-scale energy and water systems are increasingly common. These 'distributed' infrastructures are increasingly diverse—ranging in scale, technical design and governance structures. At a micro-scale, systems can provide energy and water services to a single household and are managed by direct users. Greywater systems, rainwater tanks and roof-top solar photo-voltaics are common examples. At larger scales, systems are being adopted to suit distinct communities, industrial facilities, urban precincts and even whole suburbs. Water recycling ('third-pipe'), stormwater collection and aquifer recharge systems, solar thermal and cogeneration plants are examples.

The adoption of distributed infrastructure in urban developments is particularly significant in the context of climate change and the role of community responses. They are increasingly adopted as an alternative to traditional centralised infrastructure and have the potential to combine novel social practices, which includes technologies, and governance arrangements that in theory may support reflexive learning and adaptive practices. For example, studies show that people using localised, grid-connected energy systems (compared to normal users) are often more conscious of how and when they use electricity, minimising demand at times of peak price and hence helping reduce the risk of blackouts due to over-demand (ATA, 2007). However, there are few studies about the resilience of community-scale infrastructure to climate related shocks or their ability to support adaptation.

Car park and houses at Aurora. ***Credit:** Cecily Maller*

Current regulations (including energy and water service pricing) do not adequately account for the positive externalities, or broader benefits beyond the system catchment, associated with alternative energy and water systems.

WestWyck house. ***Credit:*** *Gavin Anderson*

Enabling resilience

Resilience is the capacity of a system to maintain essential structures, functions and identity despite shocks and disturbance. In socio-technical systems (such as energy and water infrastructure) where technologies and people are interdependent and shape each other, capacity to maintain key functions is particularly important. However, this task is challenging over time because infrastructure designers, managers and users may perceive, expect and place a different value on key functions and change the way functions are valued. Furthermore, a system designed for high resilience to one type of disturbance may be vulnerable to another. System designers therefore face a critical challenge to understanding what makes infrastructures resilient to expected shocks, but also able to adjust in-line with shifting social expectations, uncertain threats, such as climate change, and novel disturbances.

Enablers of resilience are those characteristics of a socio-technical system that support expected functions to be met over time through changing circumstances, or support change in the nature and configuration of those expected functions. Enablers may be technical, social or institutional in nature. Critically, resilience enablers are interdependent, support resilience in different ways, and interact, sometimes undermining each other. For example, a high level of technical resilience in infrastructure can mean end users develop a lower capacity to adjust their behaviours in response to faults (Trentmann, 2009). This situation highlights the importance of an integrated approach to building resilience over time, incorporating and maintaining an appropriate balance of technical, institutional and social enablers.

This pilot project provides three key outcomes:

1. A preliminary set of technical, institutional and social enablers of resilience;
2. An initial conceptual framework indicating the relative value of resilience enablers under uncertainty; and
3. Preliminary assessment criteria for improving the resilience of community-scale urban infrastructure.

Based on the analysis of two case studies, Westwyck and Aurora, multiple social, technical and institutional enablers were identified as contributing to system resilience by helping to alleviate or avoid climate related disturbances to energy and water system functions including drought, heatwave, blackouts and bushfires. The principal enablers are listed in Table 1.

Community-scale energy and water systems can provide benefits that accrue to the wider community and infrastructures they sit within. These include the development of new adaptive skills, lower demand on current infrastructure and low risk experimentation.

Table 1: Summary of enablers

Technical Enablers

1. Functional diversity and redundancy – functions can be performed via alternate means and processes
2. Resource diversity and redundancy – resources can be replaced, through back-up supplies or an alternate form of resource
3. Fail-safe mechanism – impacts of faults can be minimised or contained
4. Design for modification – system designs allow for changes in system behaviour or configuration
5. Feedback mechanism – faults or changes in contextual conditions can be detected early and responded to

Institutional Enablers

1. Cross-scale learning and information exchange – knowledge gained by stakeholders at one level of system function can be passed to stakeholders at another
2. Clear lines of responsibility – responsibility for all aspects of system governance is understood accurately by all stakeholders
3. Cross-scale influence – stakeholders at one scale of system operation can influence those at another
4. Feedback mechanism – faults or changes in contextual conditions can be detected early and responded to
5. Embedded learning and experience – stakeholders responsible for system functions can understand and manage system vulnerabilities and have the capacity to respond to novel shocks.

Social Enablers

1. Knowledge – householder knowledge as a product of individual experience, community diversity and cohesion, and knowledge sharing
2. Context – practical limitations and opportunities available to the householder as a result of priorities, finances, house design and system design
3. Agency – capacity of the householder/community to self-organise and act collectively as
a result of community organization, system governance and the level of system co-management, or influence they have over the way the system is managed.

Future infrastructure investment must recognise the potential for synergies arising from integration of localised and centralised energy and water systems.

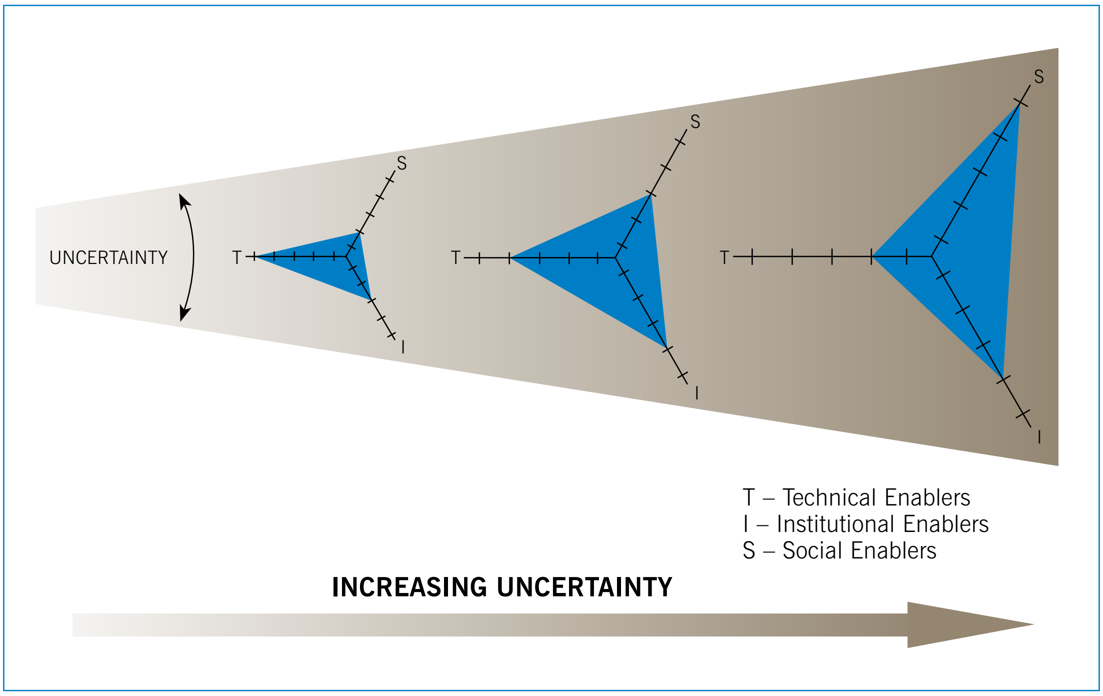
Managing climate uncertainty

The high degree of uncertainty around the timing, frequency and intensity of climate change impacts means that decisions made today on infrastructure design and investment involve considerable risk. We simply do not know the complex range of shocks that future systems will need to deal with (Attorney General's Department, 2010). However, understanding how system characteristics can support resilience in different ways and adjusting designs accordingly may help manage climate risk and uncertainty. Findings from the two pilot case studies suggest that:

- Technical enablers may prove most effective where there is high certainty about future risks. However, technical system components that provide functional diversity or redundancy ultimately rely on the assurance that environmental or institutional conditions will not change radically and that the basic make-up of system structures and functions will remain relevant.
- Institutional enablers may prove more valuable to infrastructure resilience where uncertainty over future operating conditions is greater. These factors can help institutions to identify where systems are more or less vulnerable to emerging conditions and organise resources needed to adapt system design and functions in response.
- Social enablers of resilience may prove most valuable under conditions of greatest uncertainty. In contexts where operating conditions are highly volatile or involve a high possibility of surprise, characteristics such as strong social capital and householder/community agency are likely to prove most beneficial, enabling systems and expectations to evolve rapidly when technical and institutional system components fail.

This is not to imply that technical enablers of resilience are of little value under conditions of high uncertainty or that social enablers are irrelevant in conditions of stability. Rather, it reflects that designing infrastructure (or any other system) to be resilient for a particular set of conditions can mean it is less resilient to another. Moreover, designing systems to operate in future conditions that are highly uncertain requires an emphasis on building-in the capacity for systems to change. For critical infrastructure, this means greater investment in social and institutional enablers of resilience.

Figure 2: Prioritisation of resilience enablers under differing conditions of uncertainty



Preliminary assessment criteria

The following preliminary assessment criteria are designed to be used in conjunction with the enablers of resilience indicated above in the design and planning of resilient urban infrastructure systems. Resilience is acknowledged as a dynamic state and so regular assessment and redesign of system attributes is relevant in supporting ongoing community resilience. Resilience amongst urban communities will be supported in cases where these criteria are met.

Criteria 1

Appropriate measures to recognise and respond to changes over time have been accounted for in long-term monitoring, management and maintenance strategies across the technical, institutional and social components of the urban system.

Criteria 2

Methods used to define and articulate system resilience include known risks as well as those of high uncertainty.

Criteria 3

Design and planning of community energy and water systems systematically incorporates technical, institutional and social enablers of resilience, appropriately weighted (as per Figure 2) and applied to the specific local vulnerability context.

Criteria 4

Cumulative expected benefits from the proposed energy and water systems have been assessed at multiple scales and found to be greater than for other alternative or conventional system options.

These are preliminary criteria only and it is recommended that further analyses of existing and planned housing developments are undertaken. Further analysis will inform the development of the criteria, test their capacity to assess/predict system resilience, and improve their efficacy and relevance to stakeholders in urban development.

Conclusion

Victorian energy and water systems are vulnerable to a wide range of climate change impacts that we cannot predict with certainty. Designing and planning for such systems in this 'new' emerging environment requires a more nuanced understanding of what makes these systems resilient to shocks and how interactions between users, governance structures and technologies affect their adaptive capacity.

Technical design characteristics currently form the 'backbone' of system resilience within a pre-defined set of conditions. However, communities and institutions are critical to resilience under novel or changing conditions. Planning for climate-adapted (and adaptable) systems requires designers to explicitly build-in social and institutional enablers as well as mechanisms for their maintenance.

While infrastructure managers increasingly recognise household engagement as critical to ongoing system function, significant knowledge gaps remain. Community-scale infrastructures offer a valuable laboratory for exploring these gaps and understanding how people can play an active role in maintaining system resilience through learning, exchange of information and behaviours, and by enabling collective action. Of the resilience enablers identified, the research showed that community cohesion appeared as a key factor able to support adaptation over time and ameliorate challenges to system resilience from technical and institutional failure.

Further research is required to verify and test the findings of this pilot project. In particular, additional case studies are needed that should cover alternative regulatory contexts, a range of technical and institutional configurations, and involve longitudinal assessments (over time). Research is also required to assess and compare enablers of resilience and adaptive capacity within conventional infrastructure systems. This would enable a better understanding of the relative advantages and disadvantages of community-scale and centralised systems.

The adoption and use of assessment criteria for resilient urban systems would add to the growing number of tools emerging for assessing, evaluating or measuring the performance of urban areas according to various metrics. How resilience criteria might interact with these other measures, which include ecological footprinting, liveability indices, and other planning tools for urban sustainability emerging in Australia, is another area demanding further research to ensure that gains in one area do not result in perverse outcomes for another.

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Note: Further references are available in the main report: “Resilient Urban Systems: A socio-technical study of community scale climate change adaptation initiatives” available on the VCCCAR website.

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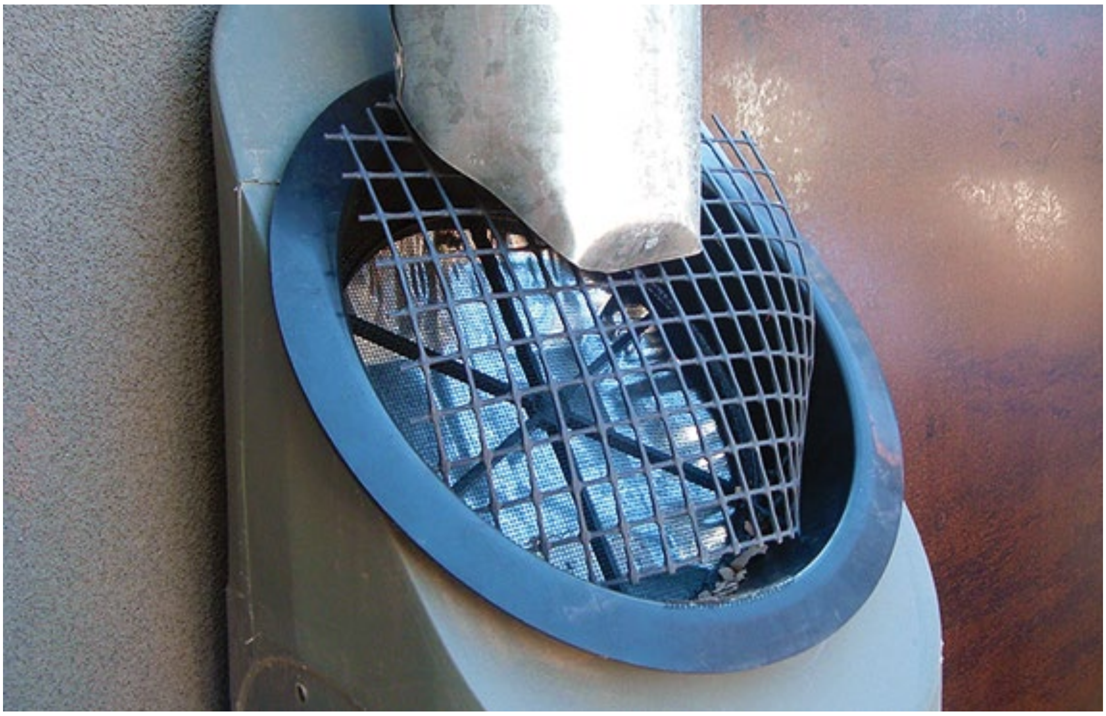
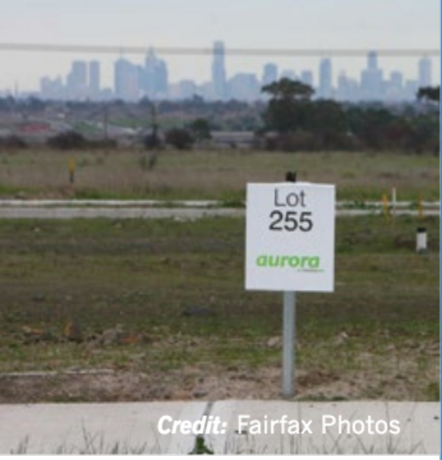


Rainwater diverters are a core feature of the alternative water systems at WestWyck. ***Credit:*** *Gavin Anderson*



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Victorian Centre for Climate Change Adaptation Research

University of Melbourne
221 Bouverie Street,
Carlton, Victoria, 3010
enquiries-vcccar@unimelb.edu.au
+ 61 (03) 8344 3095
www.vcccar.org.au

vcccar
victorian centre for climate change adaptation research

State Government Victoria

VCCCAR Publication 02/12 ISBN: 978 0 7340 4790 8

Document available from VCCCAR website at:
www.vcccar.org.au/content/pages/vcccar-publications

Layout and design by Inprint Design
www.inprint.com.au

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